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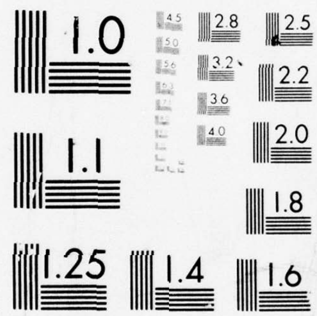

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THE EVALUATION OF TWO RANK-ORDER QUANTIZERS AS MODIFICATIONS TO THE COMMON DIGITIZER

Edward F. Mancus

DEPARTMENT OF TRANSPORTATION • UNITED STATES OF AMERICA

JULY 1977

FINAL REPORT

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16. Abstract

Two rank-order quantizers (ROQ's) were installed in the common digitizer (CD) located at the Elwood, New Jersey, National Aviation Facilities Experimental Center long range radar. Both ROQ's were designed to operate with a radar-transmitted pulse of 2 microseconds. Tests were conducted on the ROQ's and the Improved Quantizers to determine their performance with respect to one another. Test results indicated equivalent reduction in automatic clutter eliminator (ACE) total blank areas when comparing two ROQ's with the Improved Quantizer. Also, it was concluded that an ROQ employing a guard band around the target tap performed virtually the same as the Improved Quantizer in detecting search targets. The ROQ employing no guard band around the target tap resulted in a reduction in search target detection. It is recommended for future CD procurement that the ROQ be considered as a replacement for the Improved Quantizer because of its design simplicity and reliability.

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METRIC CONVERSION FACTORS

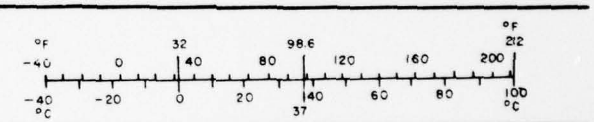
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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PREFACE

At this time I would like to acknowledge the aid of the following personnel for their help in the test and evaluation of the rank-order quantizers: Mr. William Swanseen, for his help in determining the test plan for the evaluation of the distribution-free quantizers and Messrs. Oliver Carlson, Michael Hulse, and Sherman Holland, for their assistance in collecting and processing data required for preparation of this report.

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INTRODUCTION

PURPOSE.

The purpose of this activity was to determine the technical performance of two rank-order quantizers (ROQ's) installed at the Elwood, New Jersey, common digitizer (CD) and to compare their performance to that of the existing Improved Quantizers.

BACKGROUND.

Prior extensive testing of the CD, including testing of the Production Improved Radar Quantizer Group (PIRQG) has indicated a need for improved data rate control. One of the major problems in the uses of search data has been the presence of weather and ground clutter causing an unacceptable rate of false target reports. Since a wide range of distributions is encountered in clutter, a radar quantizer having distribution-free (nonparametric) characteristics was recommended in place of a quantizer employing mean level techniques.

Two rank-order quantizers (ROQ's) of different engineering design were installed in the CD in the Elwood, New Jersey, air route surveillance radar (ARSR-2) site. One ROQ was installed by a contractor and was equipped with 24 microsecond (μs) delay line with 24, 1-μs taps as specified under the enhancement modifications of contract DOT-FA74WA-3426, specification FAA-E-2235, supplement 13. The second ROQ, first developed at the National Aviation Facilities Experimental Center (NAFEC) for testing in an Automated Radar Terminal System (ARTS-III) test site using an airport surveillance radar (ASR-5), was modified using the same delay line installation in the CD. A detailed description of this ROQ is given in the Federal Aviation Administration report entitled "Evaluation of Distribution-Free Quantizer, Several Range Binning Techniques, and an Extended Range Moving Target Indicator Video", Report No. FAA-RD-75-185 (November 1975). Both ROQ's were designed to be utilized with a radar transmitter pulse width of 2 μs.

DESCRIPTION OF EQUIPMENT.

The following paragraphs are presented to give a brief description of the equipment used to collect information on the quantizers.

COMMON DIGITIZER. The CD receives raw information from sensors (search radar, beacon radar, and height-finder radar) and converts the information to digital form. The digital data go through a statistical detection process to determine if a real target exists and gather all information pertaining to the target. The information gathered is then properly formatted to be accepted by the air route traffic control center (ARTCC). The CD messages are sent to the ARTCC through narrow-band transmission media.

FR-950 VIDEO RECORDER. The FR-950 is a wide-band rotary-head magnetic tape recorder that provides a very high order of time-base stability. The FR-950 has a dual-channel capability of recording and reproducing two wide-band

channels and two multiplexed channels of data. The recorder is used to record and play back two channels of video, radar triggers, azimuth change pulses (ACP's), azimuth reference pulse (ARP), and time.

ENROUTE TEST TARGET GENERATOR. This target generator produces targets with close similarity to real targets. This is accomplished by sampling the coherent oscillator (COHO) and stable local oscillator (STALO) frequencies of the ARSR-2. It can generate targets moving in or out in range, generate up to maximum velocity of 1,200 knots, provide target scintillation, target Doppler frequency, and antenna scan modulation. The radiofrequency (RF) test targets are inserted into the radar system through a directional coupler.

RANK-ORDER QUANTIZER. The ROQ employs a distribution-free (nonparametric) hit/miss decision-making process. A block diagram of a typical ROQ is shown in figure 1. The delay line tap spacing was established to provide two taps per interval which are equal to the approximate radar transmitter pulse width. The center tap of the delay line, called the target tap, is sampled by one input of a series of comparators. The second input of each comparator samples the surrounding video around the target sample by connecting to noise taps on both sides of the center tap of the delay line. The comparator output is high when the target tap amplitude exceeds the noise tap amplitude. The number of times the target exceeds the noise samples is called the rank of the target sample. The output of the series of comparators is fed to a high-speed summer producing an analog output. This analog output is compared to a static reference level called the rank threshold. If the rank exceeds the threshold, a hit is generated and sent to the sliding window.

FR-1800 DIGITAL RECORDER. The FR-1800 recorder/reproducer is a general purpose digital tape recorder capable of processing wide-band data within the frequency range of 400 hertz (Hz) to 1.5 megahertz (MHz). The FR-1800 records 1 to 14 channels on 1-inch-wide magnetic tape. The recorder is used to record and play back CD output messages being sent to the ARTCC along with time.

METHOD OF APPROACH

The test and evaluation program was conducted in two phases. The first phase included the establishment of standard performance criteria using static or bench test procedures. The second phase established special performance criteria using dynamic or live video test procedures. Each phase was subdivided into the performance criteria to be established, and these were accomplished as separate entities. The special performance criteria to be established are defined in appendix A. The conclusions and recommendations were based on a comparison of the performance criteria obtained with the enhancement modifications to that obtained with the baseline CD. The baseline CD is defined as including the PIRQG modification.

TEST PROCEDURES AND RESULTS

The following paragraphs describe in detail the test procedures employed and results obtained to evaluate the performance of two ROQ's to the performance of a baseline CD. Calibration of the contractor's ROQ is given in appendix B. During the 8-month period over which tests were conducted on the contractor's ROQ and the 2-month period over which tests were conducted on the NAFEC-developed ROQ, further calibration was not necessary once the initial calibration of the two systems was performed.

STATIC TESTS.

HIT SAMPLING CIRCUIT. Before commencing tests on the ROQ's, it was desired to have the selected percent noise (P_n) match the P_n being received by the sliding window. The signal-processing circuits, such as the minimum- and maximum-hit width discriminators between a ROQ and sliding window can have a significant effect on P_n regulation. Also, the hit-synchronization circuit acts as a modified peak detector, in that the quantized hits are sampled at a 1/32 nautical mile (nmi) rate and then peak detection is accomplished over a 1/4-nmi interval by ORing eight 1/32-nmi samples within the 1/4-nmi interval. If a hit was detected in any of the 1/32-nmi samples, a hit would be inserted in the sliding window for that range cell. So it was desired to have a true 1/4-nmi sampler inserted between the ROQ and the minimum-hit width discriminator in order for the actual P_n to match the selected P_n at the sliding window. This circuit, shown in figure 2, accepts amplitude-quantized hits from the ROQ and samples these hits once every 1/4-nmi clock interval at lead-edge time. A logic ONE is outputted if any portion of the quantized hit is high at the appropriate clock transition. The logic ONE is fixed in duration so as not to be affected by the signal-processing circuits before the sliding window.

PERCENT NOISE REGULATION TEST. The purpose of the P_n regulation test was to determine control over P_n regulation with several video levels and distributions for both ROQ's. These tests were conducted using inputs derived from both clutter and clutter-free environments. The clutter source was derived from video tape recordings made at the Elwood radar site. Logarithmic (LOG) and moving target indicator (MTI) video were used as inputs to the ROQ's.

First Phase. The first phase of the P_n test was accomplished using receiver noise. The ARSR-2 radar was placed in the offline mode of operation by switching the transmitted power to a dummy load. This was done to eliminate outside interference from entering the system. The receiver intermediate frequency (IF) gain was adjusted to produce 2 volts mean peak of LOG noise measured at the input of the ROQ delay line. The noise video was fed to an attenuator unit to change the video level being inserted in the rank during testing. The test configuration is shown in figure 3.

The contractor's ROQ was tested in the 24-tap and the 18-tap delay line configuration (figure 4). The NAFEC-developed ROQ was tested in the 18-tap delay line configuration. In an earlier evaluation at a terminal radar site,

the 18-tap configuration with a guard band on each side of the center tap was found to be better than the 24-tap configuration with no guard employed.

An electronic counter was used to collect hit information over several video levels. The video levels started from 150 millivolts to 2 volts mean peak LOG and MTI receiver noise for different rank threshold settings. The results of these tests are displayed in figures 5, 6, and 7. Results indicate that the actual P_n output of both 18-tap configurations were within ± 5 percent of the desired P_n. This was also true over the entire range of input levels.

The P_n results from the contractor's ROQ employing the 24-tap delay line configuration were within ± 5 percent of selected P_n except at the low video noise of 150 millivolts. A slight positive voltage on the center tap bias was believed to be the cause of the P_n rise at low video noise levels.

Second Phase. The second phase of the P_n regulation test was accomplished using video tapes containing various weather patterns and density. The objective was to compare the P_n regulation of each ROQ when areas of weather clutter occur surrounded by a clear-air environment. A clutter indicator circuit, shown in figure 8, was designed and installed in the NAFEC ROQ for this test. The contractor's ROQ was already equipped with a clutter indicator circuit. The clutter-indicating signal was used to collect hit samples generated by clutter environments. The clutter indicator signal was ANDed with the output of the hit-sampler circuit so hits produced from clutter would be counted. The clutter hit samples were inserted into an electronic counter, and a printer recorded the counts each scan for 50 scans. Each 50-scan run was averaged and divided by a 100-percent hit count to produce the P_n data. The 100-percent hit count was obtained by placing +5 volts at the input of the hit-sampling circuit. This counted the total number of clock pulses at the output of the sampling circuit. To obtain P_n for clear air on the same tapes, the clutter-indicating signal was inverted. The results are shown in figure 9. The results indicated that clutter environment did not affect the ROQ's ability to regulate P_n.

PERCENT FALSE ALARM TEST. The percent false alarm (P_{FA}) test was to establish the false alarm rate of the ROQ's. The test was also to determine the proper rank threshold settings for both ROQ's to correspond to a 10^{-6} false alarm rate. Again, one-half volt of log receiver noise was inserted in the ROQ's. Two delay line configurations for the contractor's ROQ were tested over a range of selected P_n. The delay line configurations were the 24-tap system, with no guard band around the center tap, and an 18-tap system, with a 4-microsecond guard band on each side of the center tap. Only the 18-tap system of the NAFEC ROQ was considered. Also P_{FA} was collected on the Improved Quantizer to be used for baseline comparison. The lead-edge threshold (T_L) was 7 for the Elwood sliding window of 12. The trail-edge threshold (T_T) was 5, and the automatic clutter eliminator (ACE) was in the OFF position. The results are displayed in figure 10. The NAFEC ROQ showed the greatest reduction in false alarms, while the contractor's ROQ configurations followed closely the false alarm rate of the Improved Quantizer.

PERCENT QUANTIZATION TEST. Due to the late fabrication of the NAFEC-developed ROQ and its installation in the CD, percent quantization (P_Q) data were not collected on it. It was felt, because of time limitation, that dynamic tests were more useful in evaluating the performance of the NAFEC ROQ. Therefore, P_Q data were only collected on the contractor's ROQ.

The purpose of this test was to establish the relative sensitivity between the ROQ in the different delay line configurations and the Improved Quantizer for pulse detection in receiver noise. Both MTI and LOG receiver noise levels were set at 0.5 volts mean peak. A 2-microsecond pulse from an RF generator was inserted into the directional coupler of the radar. The P_Q test configuration is shown in figure 11. The generator is triggered once every sweep at an optimum range setting. Since statistical detection is based on cells, there are positions relative to cell boundaries that produce optimum detection and others, poor detection. Due to delay differences in video between the ROQ and the Improved Quantizer, the range of the ring target was optimized for both individually. The signal strength was varied from minimum discernable signal (MDS) to +9 decibels (dB) above MDS.

A spare AND gate in the CD was used to gate the quantized hits at the input of the sliding window with a fixed-range pulse, 1 μs wide. The 1-μs fixed-range pulse generated by a pulse generator triggered once every sweep was delayed in range to overlap the quantized hits (standardized to 3 μs) generated only by the ring pulse being inserted into the radar. The detection scheme is based on the following relationship:

$$P_Q = \frac{\text{Actual No. of hits per scan (Ahits)}}{\text{Maximum possible hits per scan (Mhits)}}$$

where Mhits = pulse repetition frequency (PRF)(360)X scan time (9.6 seconds)

The results are presented in tables 1 and 2. Table 1 shows a sensitivity variation of less than ±5 percent in P_Q using LOG video between the contractor's ROQ employing the 24-tap configuration and the Improved Quantizer. Comparison between the ROQ employing the 18-tap configuration and the Improved Quantizer indicated a variation of less than 10 percent in P_Q for pulse detection with the Improved Quantizer having an edge in sensitivity. The P_Q results of table 2 using MTI video were approximately equivalent between the contractor ROQ employing both delay line configuration and the Improved Quantizer with one exception. The results taken at 4 percent P_n indicated a sensitivity reduction in the contractor's ROQ in the 24-tap configuration compared to the Improved Quantizer.

PERCENT DETECTION TEST. The objective of the percent detection (P_D) test was to determine the relative sensitivity of the ROQ's as part of the CD system. The CD settings were T_L= 7, T_L-T_T=2, ACE OFF, and P_n set for 10^{-6} false alarm rate. Thirty-two test targets generated by the enroute test target generator were fed through a directional coupler to the radar and added to 0.5 volts of receiver noise. The targets, 39 ACP's wide, traveled out in range in such a way that, between each scan, their movements were not equal to or multiples of

TABLE 1. PERCENT QUANTIZATION TEST RESULTS USING LOG RECEIVER NOISE

A. CONTRACTOR'S ROQ, 24-TAP CONFIGURATION

P_n Selected	INPUT PULSE SIGNAL STRENGTH +9 dB	+6 dB	+3 dB	+1 dB	MDS
4.0	83.4	60.7	36.3	26.4	22.2
8.0	96.9	80.5	53.4	41.5	35.2
12.0	98.8	86.0	62.6	49.4	44.4
16.0	99.3	90.2	68.0	56.8	50.6
20.0	99.5	92.1	73.1	61.8	56.5

B. CONTRACTOR'S ROQ, 18-TAP CONFIGURATION

P_n Selected	INPUT PULSE SIGNAL STRENGTH +9 dB	+6 dB	+3 dB	+1 dB	MDS
5.26	93.3	65.6	37.7	27.3	23.1
10.52	96.7	76.8	49.6	37.6	32.0
15.78	98.8	86.0	62.0	51.0	44.1
21.04	99.3	90.7	70.5	58.0	52.4
26.32	99.6	93.0	76.3	65.0	59.1

C. PRODUCTION IMPROVED RADAR QUANTIZER

P_n Selected	INPUT PULSE SIGNAL STRENGTH +9 dB	+6 dB	+3 dB	+1 dB	MDS
4.0	85.4	63.8	40.4	27.7	22.6
5.26	92.9	71.5	46.5	32.6	27.4
8.0	94.8	76.7	52.9	40.0	33.7
12.0	96.9	85.5	63.4	50.5	43.0
15.0	97.1	88.1	68.2	55.0	47.6

TABLE 2. PERCENT QUANTIZATION TEST RESULTS USING MTI RECEIVER NOISE

A. CONTRACTOR'S ROQ, 24-TAP CONFIGURATION

P_n Selected	INPUT PULSE SIGNAL STRENGTH +9 dB	+6 dB	+3 dB	+1 dB	MDS
4.0	32.0	29.8	22.9	17.7	15.6
8.0	66.5	51.8	38.9	30.9	26.6
12.0	74.6	59.8	47.3	39.2	34.9
16.0	78.5	66.6	56.1	46.3	41.9
20.0	81.9	71.4	59.7	52.1	48.8

B. CONTRACTOR'S ROQ, 18-TAP CONFIGURATION

P_n Selected	INPUT PULSE SIGNAL STRENGTH +9 dB	+6 dB	+3 dB	+1 dB	MDS
5.26	57.7	48.8	34.1	28.1	24.6
10.52	67.9	60.2	47.7	39.7	35.9
15.78	74.0	67.9	55.2	48.5	43.9
21.04	77.9	72.4	62.3	55.0	51.9
26.32	81.8	76.0	67.5	60.5	58.1

C. PRODUCTION IMPROVED RADAR QUANTIZER

P_n Selected	INPUT PULSE SIGNAL STRENGTH +9 dB	+6 dB	+3 dB	+1 dB	MDS
4.0	54.3	46.8	34.7	27.1	25.3
5.26	58.5	50.1	38.2	30.0	28.4
8.0	62.7	53.3	41.3	36.5	32.7
12.0	67.2	56.8	46.7	42.2	37.9
15.0	70.2	60.1	51.1	44.9	40.9

a range cell 1/4 nmi in depth. This was done in order that targets would be located in different positions relative to cell boundaries for each scan. Target strength was varied from MDS to +9 dB above MDS. The signal strength is attenuated on both sides of the test target in such a way as to simulate the actual scanning of a search radar sweeping across the target. In effect, the antenna scan pattern of a 9-dB test target generated by the enroute test target generator produces a target with a 3-dB target width, approximately 10 ACP's. Target counts were recorded over several P_n settings. The resulting P_D versus signal strength data are shown in figure 12. The results indicated the system sensitivity was reduced using both ROQs employing the 18-tap configuration when compared to the Improved Quantizer. The difference in system sensitivity increased as target signal strength increased. The sensitity of the contractor's ROQ employing the 24-tap configuration was reduced still further.

DYNAMIC TEST.

The dynamic test required repeatable video as input to the CD in order to compare the performance of each ROQ configuration to the performance of the Improved Quantizer. The FR-950 video recorder provided the video repeatability needed. Four video tapes were used to evaluate the dynamic operation of each quantizer. Three of these video tapes were recorded at the Elwood, New Jersey, ARSR-2 radar site. The fourth video tape was recorded at Paso Robles, California, ARSR-2 radar site. A description of each tape alone with CD settings for each site is given in appendix C. The CD output messages were recorded on an FR-1800 digital recorder. The FR-1800 tapes were subsequently replayed to generate input tapes for data reduction and analysis routines. A block diagram of the dynamic test set up is shown in figure 13.

SEARCH DATA COUNT AND ACE TOTAL BLANK AREA TEST. The search data count and the ACE total blanking data were collected while FR-1800 recordings were made for each configuration. A comparison of those data is presented in tables 3 and 4. The ACE total blank area presented is the average number of range cells per scan in which T_L exceeds the sliding window size. The total number of range cells per scan is approximately 2.866 x 10^{+6} for Elwood radar site.

ACE total blanking did not occur except during weather tape 76-03. Some blanking was recorded during runs using the contractor's ROQ in both delay line configurations. The results indicated both ROQ's were as effective as the Improved Quantizer in eliminating ACE blanking. The search data counts between the ROQ's employing the 18-tap delay line configuration and the Improved Quantizer were similar as produced by clear-air tape 74-20 and the scattered weather clutter tapes 76-07 and 75-09. The results of clear-air tape 75-02 produced a small decrease in search targets by both ROQ's, while the results of weather tape 76-07 indicated a small increase in search targets by both ROQ's.

The contractor's 24-tap configuration consistently resulted in lower counts using clear-air and weather clutter tapes. The results obtained by the Paso Robles tape with extended ground clutter displayed an increase in search data using the contractor's ROQ's in both delay line configurations.

TABLE 3. AUTOMATIC CLUTTER ELIMINATOR TOTAL BLANK AREA IN RANGE CELLS PER SCAN

FR-950 Tapes	Standard Improved Quantizer	NAFEC ROQ 18-Tap Config.	Contractor's ROQ 18-Tap Config.	Contractor's ROQ 24-Tap Config.
Elwood 74-20	0	0	0	0
Elwood 76-07	0	0	0	0
Paso Robles No. 2	0	0	0	0
Elwood 76-03	0	0	4.11	0.47

TABLE 4. TOTAL SEARCH DATA COUNTS PER SCAN

FR-950 Tapes	Standard Improved Quantizer	NAFEC ROQ 18-Tap Config.	Contractor's ROQ 18-Tap Config.	Contractor's ROQ 24-Tap Config.
Elwood 74-20	334.30	349.30	343.00	302.60
Elwood 76-07	111.10	121.80	129.50	106.30
Paso Robles No. 2	79.75	76.25	94.40	93.40
Elwood 76-03	94.40	101.45	91.7	84.3
Elwood 75-09	141.55	142.25	143.55	-
Elwood 75-02	102.75	92.35	93.76	-

TRACK BLIP/SCAN RATIO. This series of tests was run to determine how well the National Airspace System (NAS) tracking routine would work using the CD with different ROQ configurations. FR-1800 tapes prepared earlier were used as inputs to the NAS computer and the computer display channel (CDC) equipment. NAS 3d2.0 tracker monitored search targets, the courses of which proceeded from clear air into weather clutter or ground clutter areas. Sets of system analysis recording (SAR) tapes for each video were collected for the different quantizer configurations. In each set of tapes, the same targets were tracked. A normalized start and stop time was established in which to gather information. A summary of track blip/scan ratios is given in tables 5 and 6. The track blip/scan data results indicated little difference in performance between the CD employing the PIRQG and the ROQ's in the 18-tap delay line configuration. Both 18-tap ROQ's were within 2 percent of the Improved Quantizers performance. As for the contractor's ROQ employing the 24-tap delay line configuration, the results showed about 20-percent reduction in track blip/scan ratio compared to the Improved Quantizer.

TRAIL BLIP/SCAN RATIO. The FR-1800 recordings made using the Improved Quantizer and both ROQ's were reformatted to digital tapes that were used as inputs to the TAD program which made use of a cathode-ray tube (CRT) display. The CRT, which was interfaced with the computer, presented CD output messages with enough refresh capability to enable an operator to correlate individual returns to a search trail. The same search targets whose course proceeded from clear air into weather clutter areas were selected. Printouts of correlated targets from each set of tapes were compared to evaluate the performance of each quantizer configuration. A normalized start and stop time was established for each target used to gather information. Tables 7 and 8 give a summary of the trail blip/scan ratio. The results indicated the Improved Quantizer held a slight edge in detection over the ROQ's with the 18-tap delay line configuration. The contractor's ROQ with the delay line in the 24-tap configuration showed greater than 20-percent reduction in trail blip/scan ratio than the Improved Quantizer.

TABLE 5. TRACK BLIP/SCAN RATIO (PERCENT)

	FR-950 No. 74-20			FR-950 Paso Robles No. 2		
Runs	Improved Quantizer	Contractor's 24-Tap ROQ	Contractor's 18-Tap ROQ	Improved Quantizer	Contractor's 24-Tap ROQ	Contractor's 18-Tap ROQ
1	94.1	94.1	88.2	75.0	83.3	75.0
2	76.2	54.8	71.4	80.0	57.1	81.3
3	95.2	73.8	97.6	93.5	71.0	100.0
4	100.0	76.9	100.0	94.7	63.2	63.2
5	82.1	67.9	71.4	75.0	57.1	78.6
6	100.0	70.4	96.3	84.4	64.3	84.4
7	100.0	91.3	91.3	92.6	59.3	96.3
8	73.9	63.2	89.5	71.4	57.1	71.4
9				71.4	50.0	76.2
Avg.	89.7	71.9	87.5	82.0	62.4	80.7

TABLE 6. TRACK BLIP/SCAN RATIO (PERCENT)

	FR-950 No. 76-07			FR-950 No. 74-13			
Runs	Improved Quantizer	Contractor's 18-Tap ROQ	NAFEC 18-Tap ROQ	Improved Quantizer	Contractor's 24-Tap ROQ	Contractor's 18-Tap ROQ	NAFEC 18-Tap ROQ
1	81.3	70.8	66.7	88.5	65.4	84.6	88.5
2	78.9	78.9	84.2	95.4	76.9	98.5	98.5
3	90.3	90.3	90.3	83.0	NT	98.1	96.2
4	64.7	61.9	73.3	85.7	61.9	81.0	81.0
5	72.7	78.8	87.9	100.0	50.0	100.00	100.0
6	66.7	55.6	50.0	97.3	62.2	89.2	89.2
7	57.1	85.7	85.7	88.2	61.8	88.2	94.1
8	80.0	87.5	83.3	90.9	NT	90.9	96.4
9	84.2	78.3	77.6	100.0	57.1	100.0	100.0
Avg.	78.3	76.6	77.7	94.1	64.4	92.8	94.1

Note: The average does not include runs 3 and 8.

TABLE 7. TRAIL BLIP/SCAN RATIO (PERCENT)

	FR-950 No. 74-20			FR-950 Paso Robles No. 2		
Runs	Improved Quantizer	Contractor's 24-Tap ROQ	Contractor's 18-Tap ROQ	Improved Quantizer	Contractor's 24-Tap ROQ	Contractor's 18-Tap ROQ
1	92.1	44.7	81.6	85.7	64.3	95.2
2	64.9	43.9	50.9	68.6	49.0	78.4
3	70.9	54.5	63.6	69.0	47.9	70.4
4	67.3	52.7	67.3	70.3	48.4	67.2
5	75.7	59.5	64.9	63.6	38.2	52.7
6	85.2	55.6	88.9	90.2	65.9	95.1
7	88.1	71.4	88.1	40.4	32.7	46.2
8	96.0	60.0	88.0	75.0	47.5	60.0
9	93.9	75.5	89.8	83.9	51.6	64.5
10	95.0	55.0	92.5			
Avg.	80.9	56.9	75.3	70.2	48.5	69.1

TABLE 8. TRAIL BLIP/SCAN RATIO (PERCENT)

	FR-950 No. 76-07			FR-950 No. 74-13			
Runs	Improved Quantizer	Contractor's 18-Tap ROQ	NAFEC 18-Tap ROQ	Improved Quantizer	Contractor's 24-Tap ROQ	Contractor's 18-Tap ROQ	NAFEC 18-Tap ROQ
1	79.6	77.6	83.7	87.5	66.7	97.9	97.9
2	75.0	46.4	57.1	88.6	36.4	40.9	70.5
3	65.0	70.0	70.0	88.1	61.9	85.7	90.5
4	61.3	61.3	54.8	73.7	44.7	60.5	78.9
5	75.0	62.5	62.5	97.9	72.9	91.7	95.9
6	85.0	87.5	82.5	96.0	52.0	90.0	94.1
7	84.6	65.4	69.2	91.3	78.3	82.6	87.0
8	83.3	83.3	77.8	100.0	54.9	94.1	96.1
9				62.9	37.1	48.6	62.9
10				81.8	63.6	90.9	95.5
Avg.	75.8	70.6	71.4	87.5	56.1	79.1	88.0

SUMMARY OF RESULTS

The results obtained during the evaluation of the ROQ's as modifications to the CD are summarized as follows:

1. Both ROQ's regulated the probability of noise in thermal and clutter conditions over a wide range of rank threshold settings and input noise levels.

2. The probability of quantization obtained on the contractor's ROQ employing no guard band showed a sensitivity variation of less than ±5 percent compared to the Improved Quantizer for static conditions using LOG receiver noise. The ROQ employed a 4-μs guard band sensitivity variation that was less than ±10 percent of the PQ obtained by the Improved Quantizer. The PQ results using MTI video was approximately equivalent between the contractor's ROQ in both delay line configurations and the Improved Quantizer.

3. The probability of detection obtained in static conditions on moving targets was reduced using the NAFEC ROQ, and the contractor's ROQ employing a guard band around the target tap. The contractor's ROQ with no guard band around the target tap resulted in a significant reduction in probability of detection.

4. The ROQ's were as effective in eliminating ACE total blanking as was the Improved Quantizer.

5. The search data count virtually remained the same using both ROQ's employing the 18-tap delay line configuration for several clear-air and weather clutter video tapes. A 10-percent reduction in search data count occurred when the contractor's ROQ with the 24-tap delay line was used.

6. The search target tracking performance remained virtually the same using the 18-tap delay line configuration with both ROQ's. A decrease in search target tracking performance occurred employing the 24-tap delay line configuration for the contractor's ROQ.

7. The search target trail performance was consistent between both ROQ's employing the 18-tap delay line configuration and the Improved Quantizer. A large reduction in search target trail performance occurred when the contractor's ROQ was employed with the 24-tap delay line configuration.

8. System reliability proved to be superior employing the ROQ over the Improved Quantizer over long periods of time. The improvement is stability due to design simplicity.

CONCLUSIONS

1. A 4-μs guard band around the center tap of the delay line is necessary for improved target detection when using a rank-order quantizer (ROQ).

2. The ROQ's produce more homogeneous hit patterns than the Improved Quantizer, eliminating most hit fringing around weather clutter boundaries.

3. The false alarm rate is the same for the common digitizer (CD) with the ROQ's or the Improved Quantizer used as search target detectors.

4. The ROQ's are simpler to calibrate and show better stability over a longer period of time than the Improved Quantizer.

RECOMMENDATIONS

It is recommended that the ROQ designed for an ARSR pulse width of 2 μs not be retrofitted into the CD. If, in the future, new specifications are drawn up for the CD, the ROQ should be included, because of its simplicity of design and high reliability.

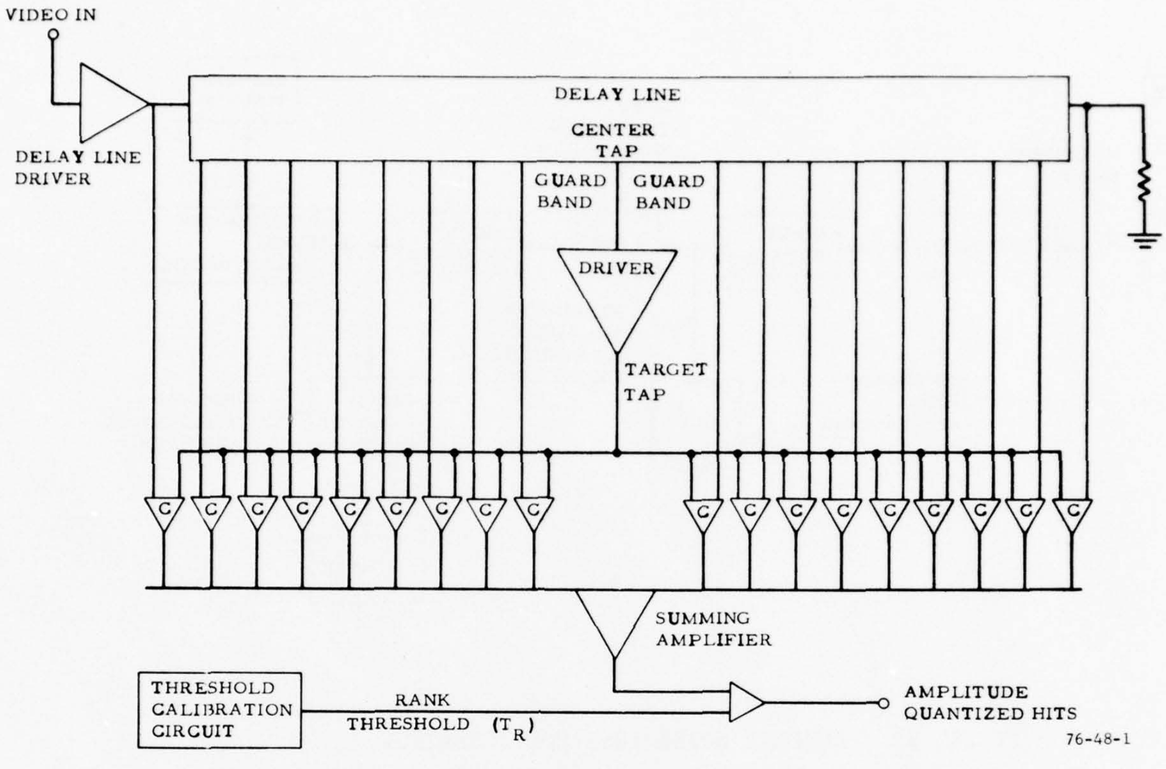


FIGURE 1. TYPICAL RANK-ORDER QUANTIZER

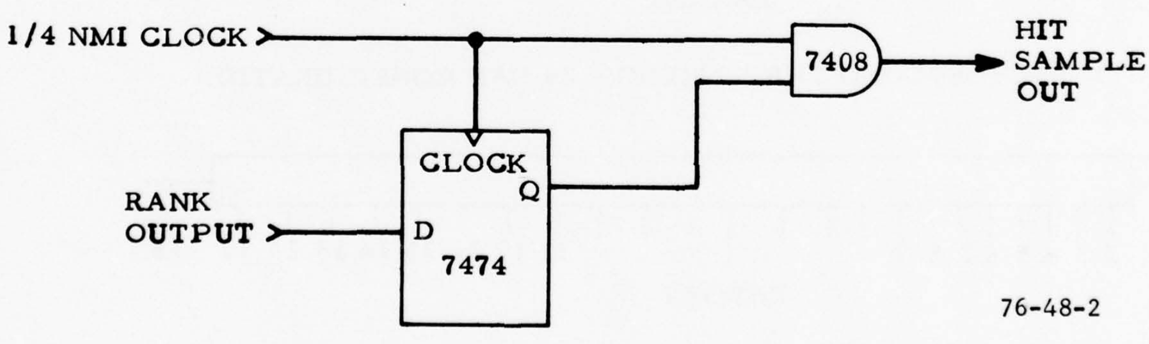


FIGURE 2. LOGIC DIAGRAM OF HIT SAMPLING CIRCUIT

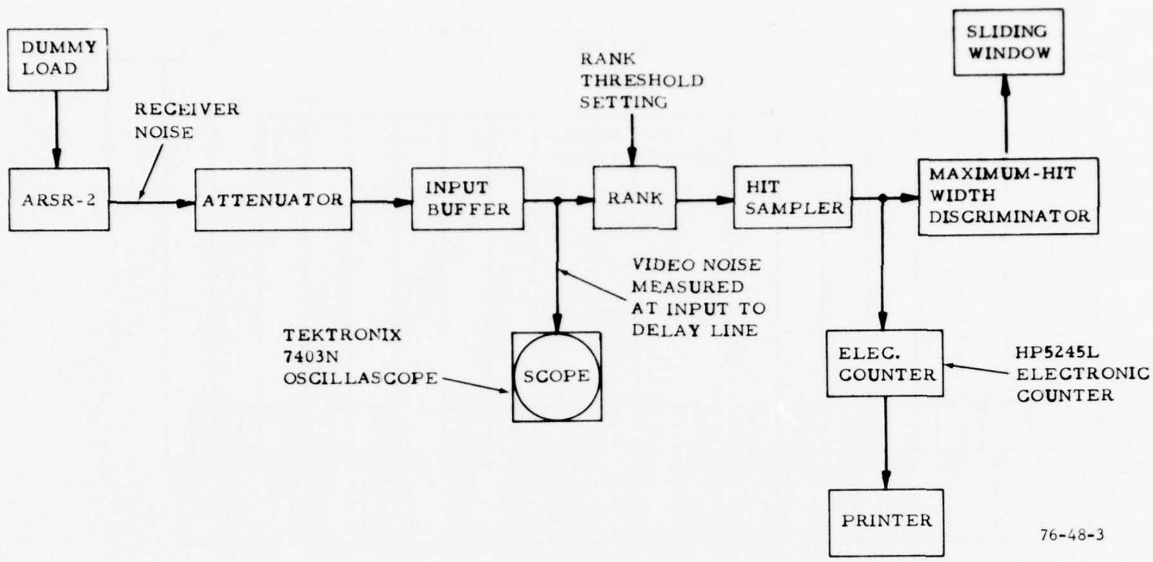


FIGURE 3. PERCENT NOISE TEST CONFIGURATION

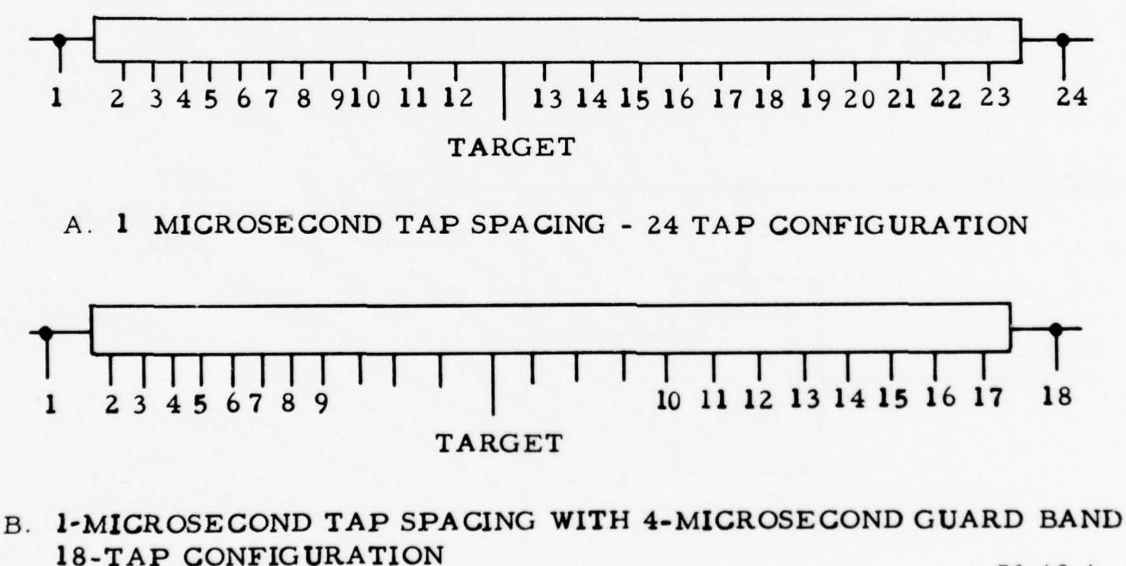


FIGURE 4. DELAY LINE TAP SPACING CONFIGURATION

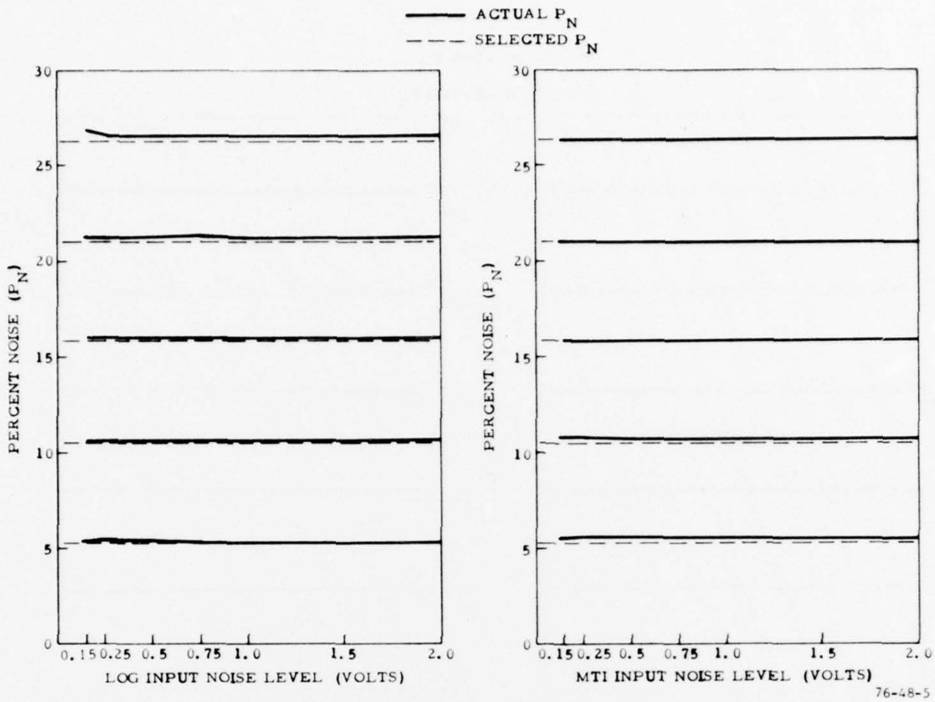


FIGURE 5. CONTRACTOR's RANK-ORDER QUANTIZER 18-TAP SYSTEM

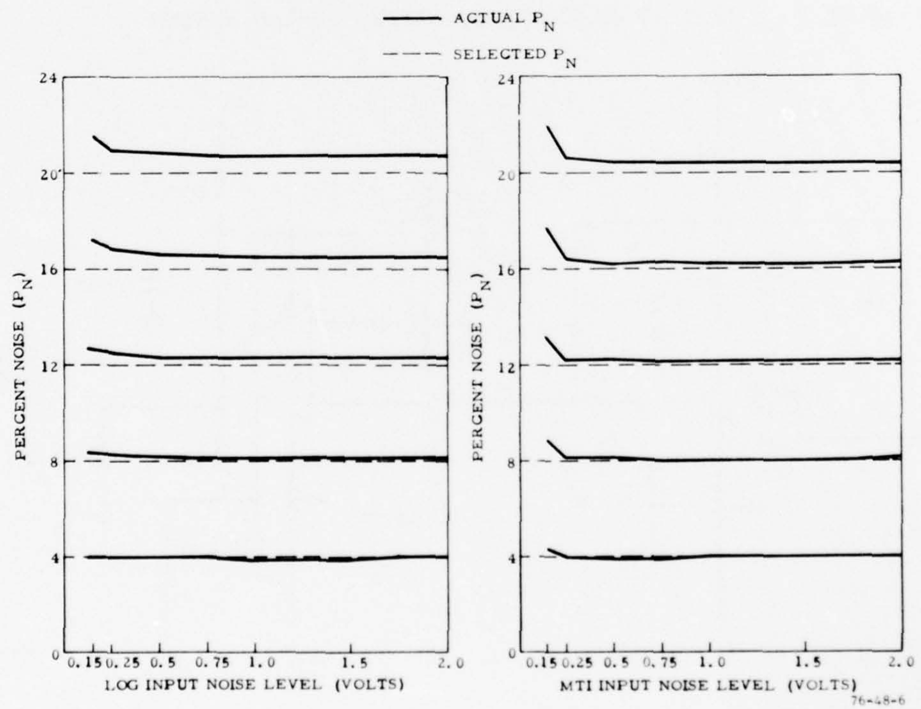


FIGURE 6. CONTRACTOR's RANK-ORDER QUANTIZER 24-TAP SYSTEM

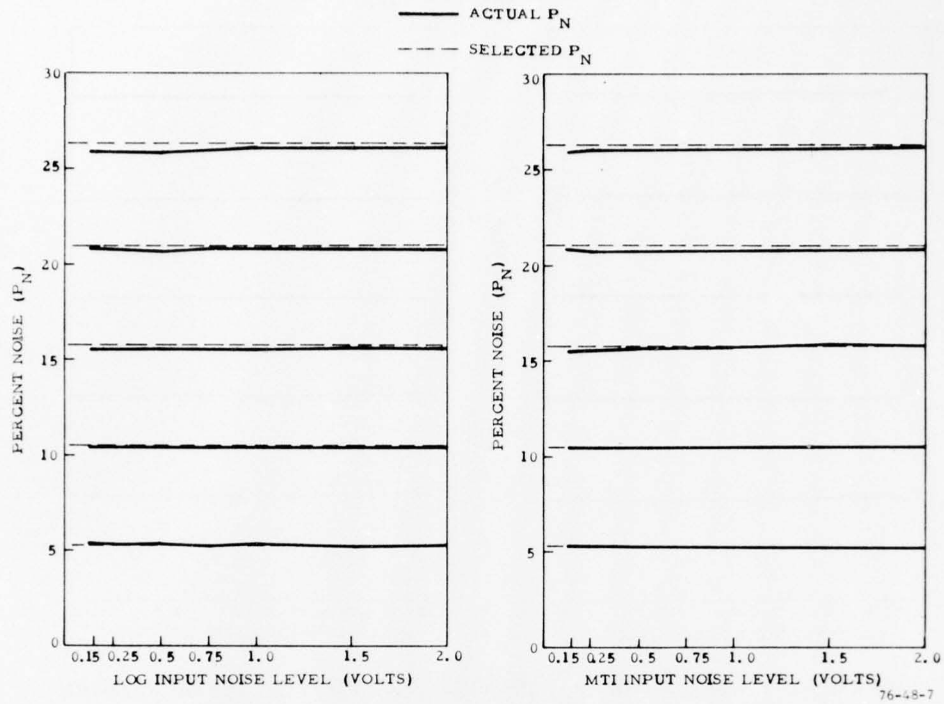


FIGURE 7. NAFEC RANK-ORDER QUANTIZER 18-TAP SYSTEM

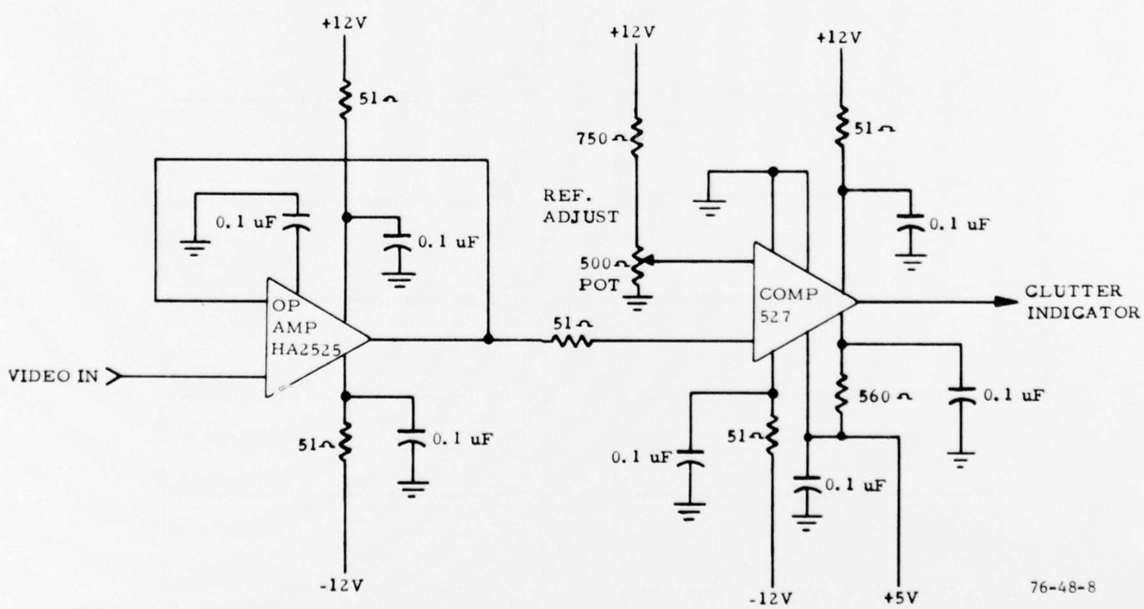


FIGURE 8. CLUTTER REFERENCE CIRCUIT

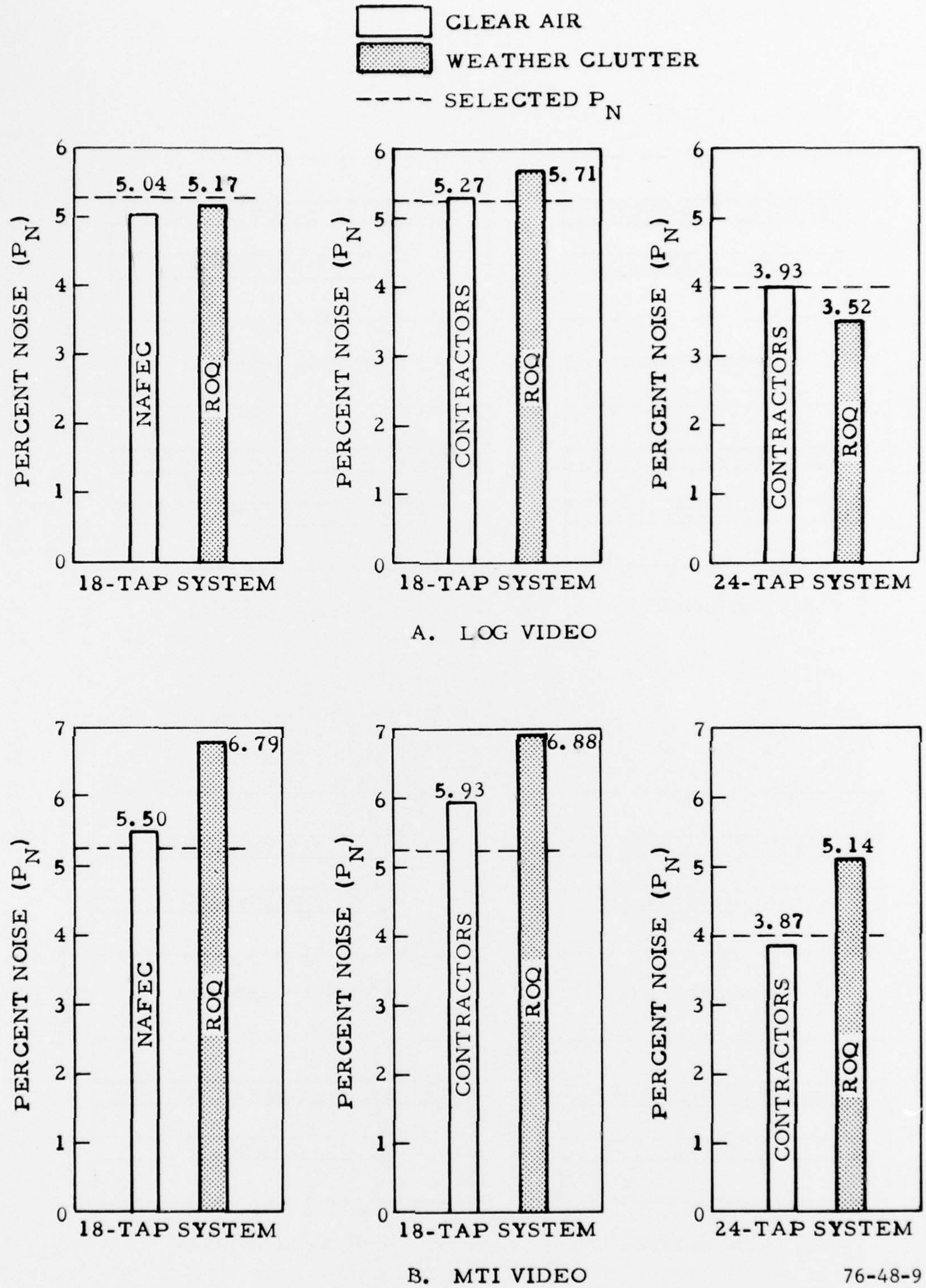
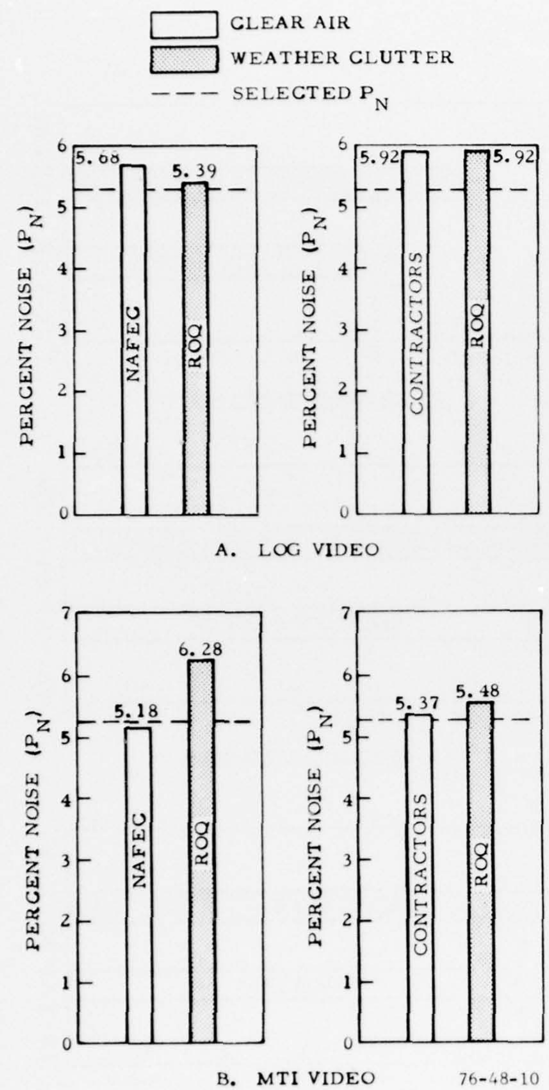


FIGURE 9. PERCENT NOISE FOR VARIOUS WEATHER SAMPLES (SHEET 1 of 3)



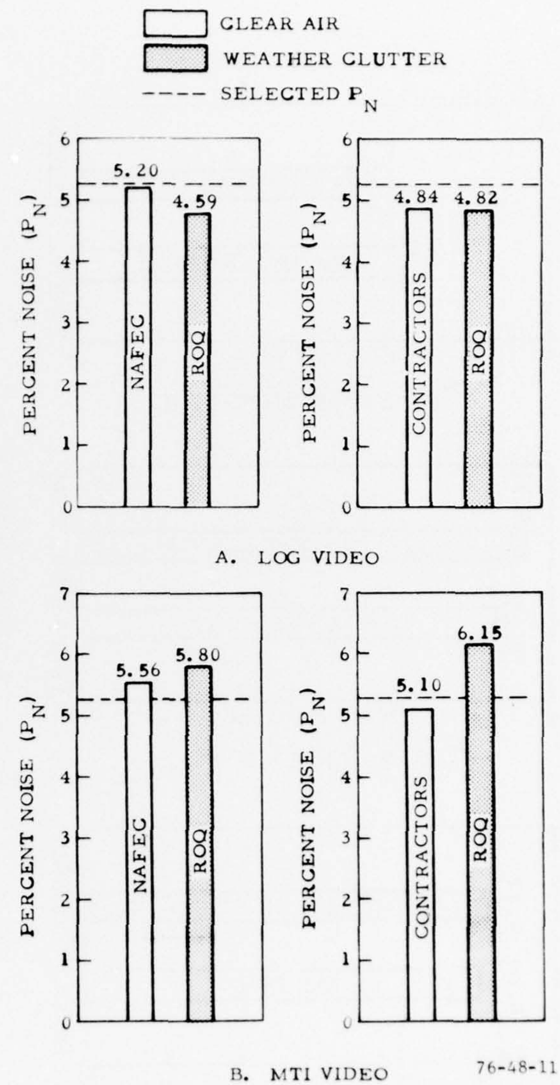


FIGURE 9. PERCENT NOISE FOR VARIOUS WEATHER SAMPLES (SHEET 2 of 3)

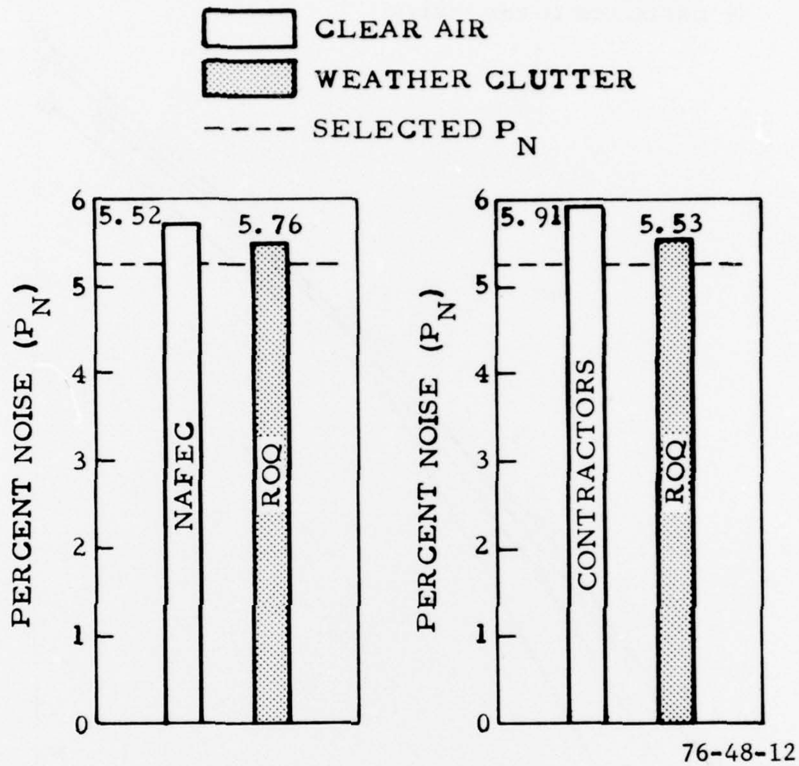


FIGURE 9. PERCENT NOISE FOR VARIOUS WEATHER SAMPLES (SHEET 3 of 3)

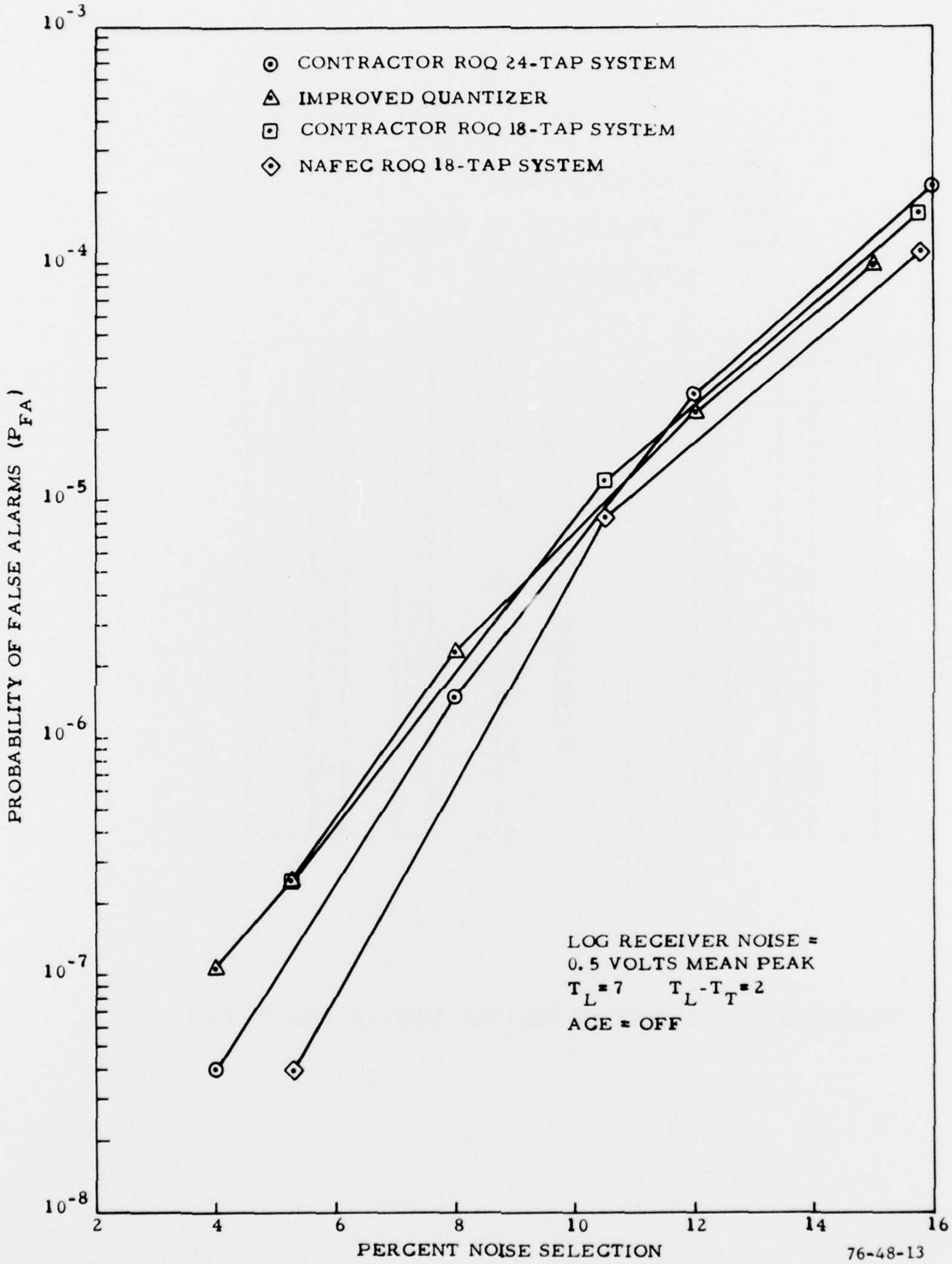


FIGURE 10. PERCENT NOISE SELECTION (P_n)

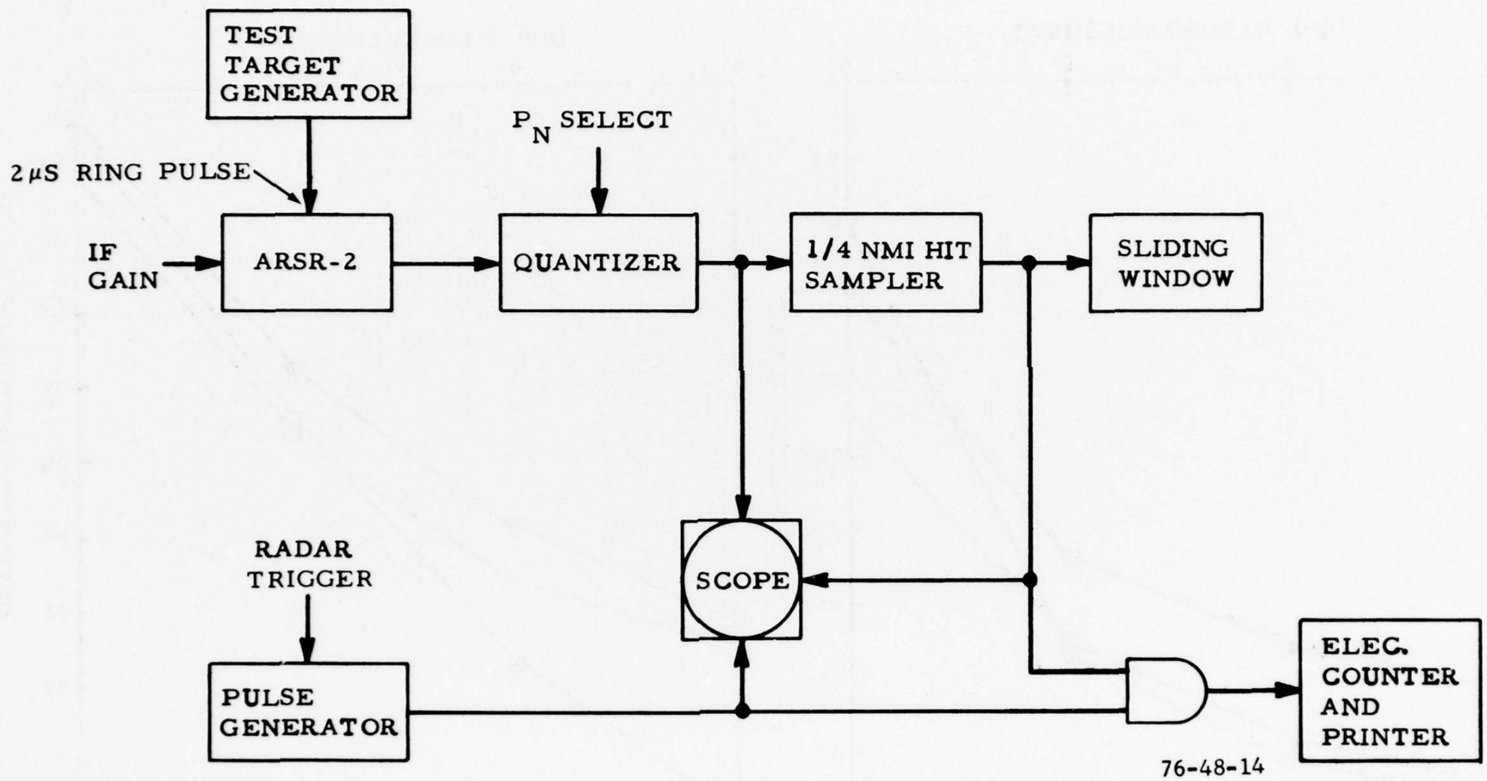


FIGURE 11. PERCENT QUANTIFICATION TEST CONFIGURATION

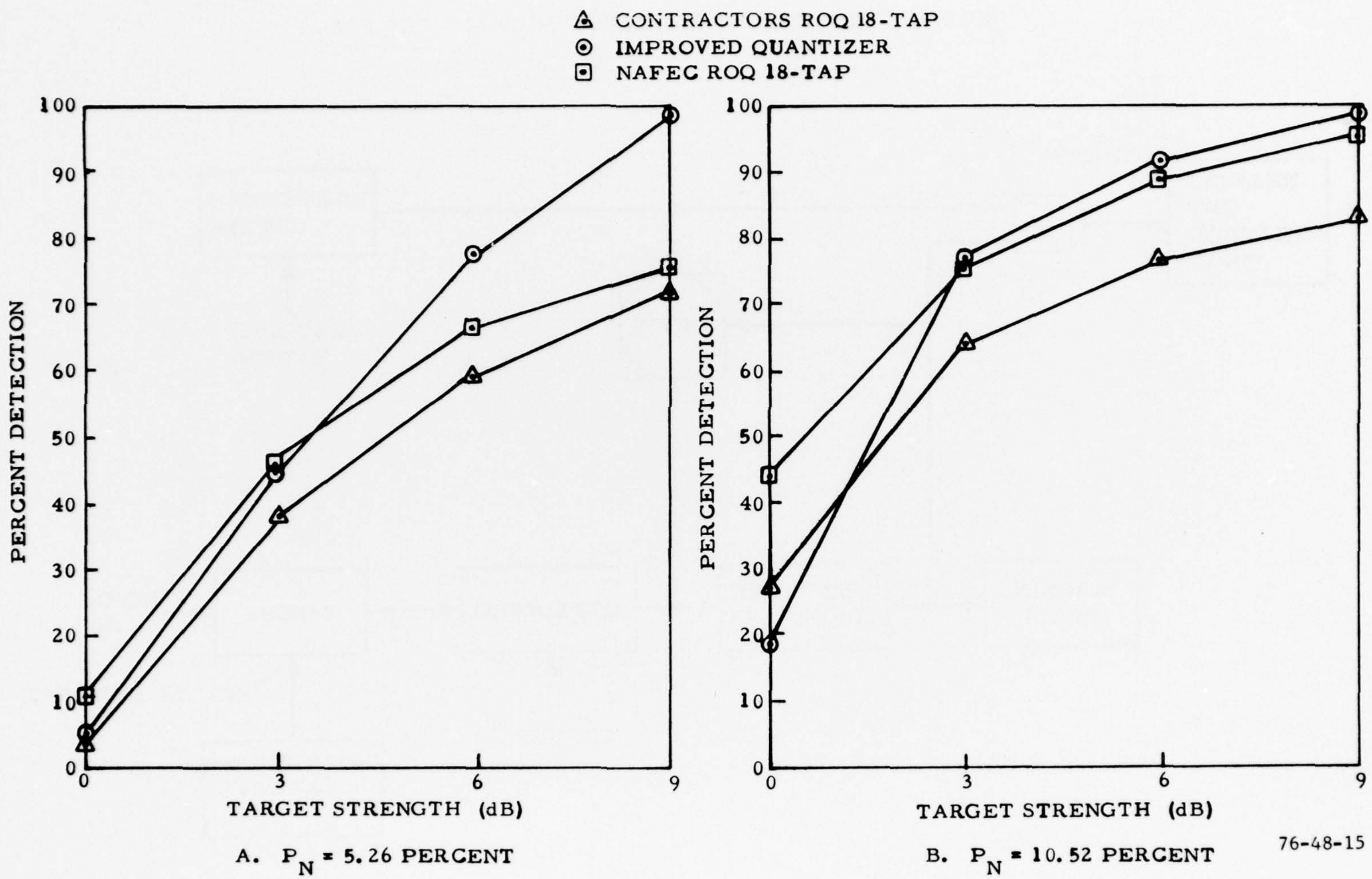


FIGURE 12. PERCENT DETECTION TEST RESULTS (SHEET 1 of 4)

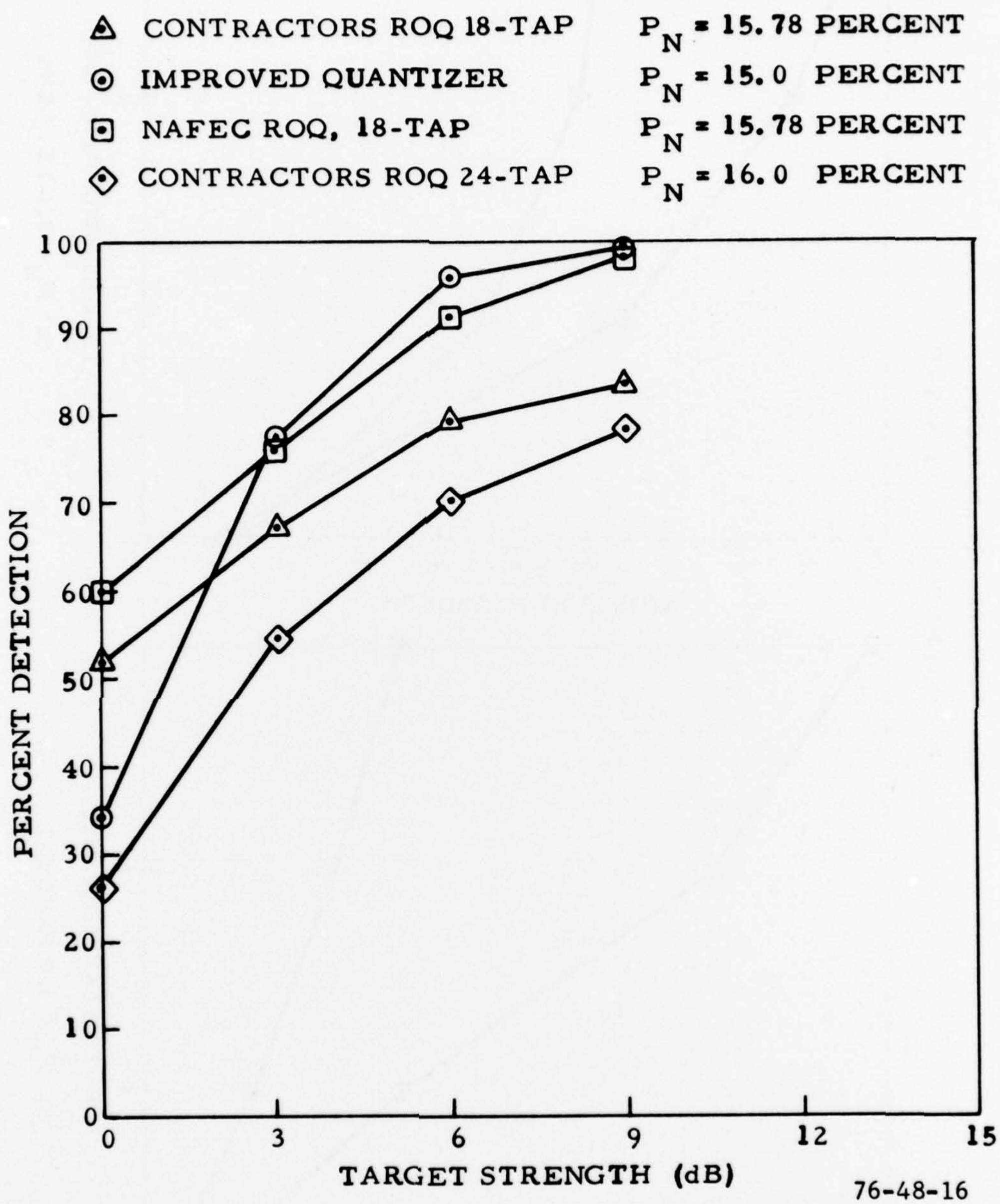


FIGURE 12. PERCENT DETECTION TEST RESULTS (SHEET 2 of 4)

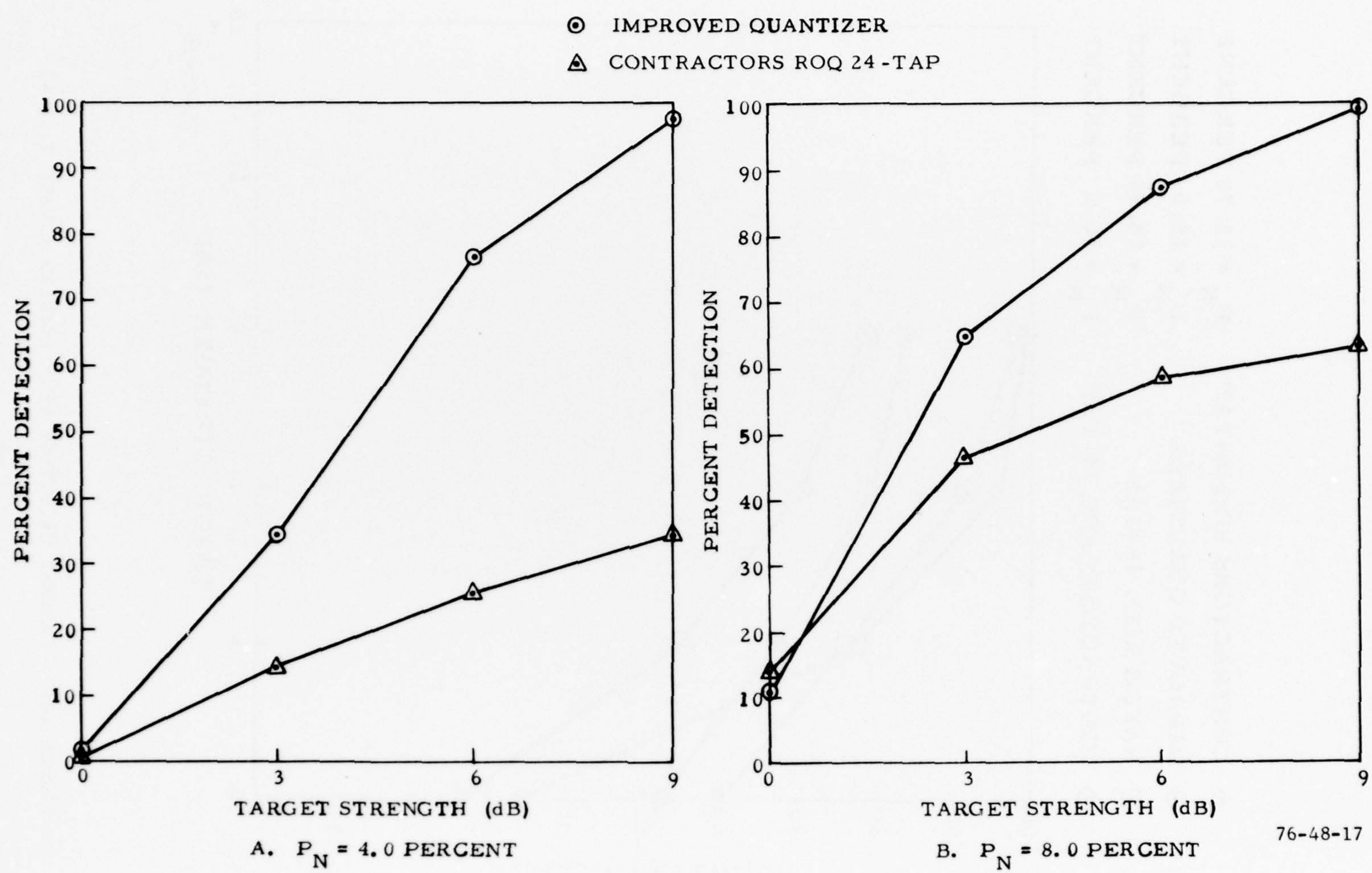


FIGURE 12. PERCENT DETECTION TEST RESULTS (SHEET 3 of 4)

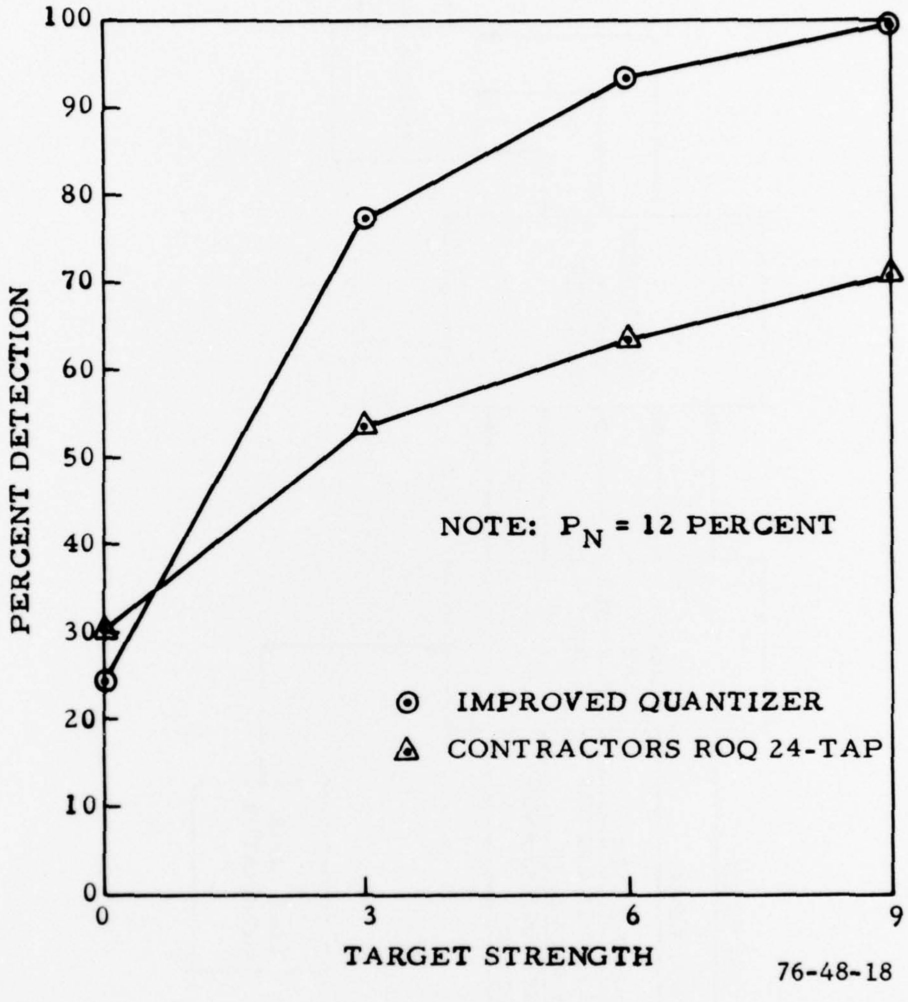


FIGURE 12. PERCENT DETECTION TEST RESULTS (SHEET 4 of 4)

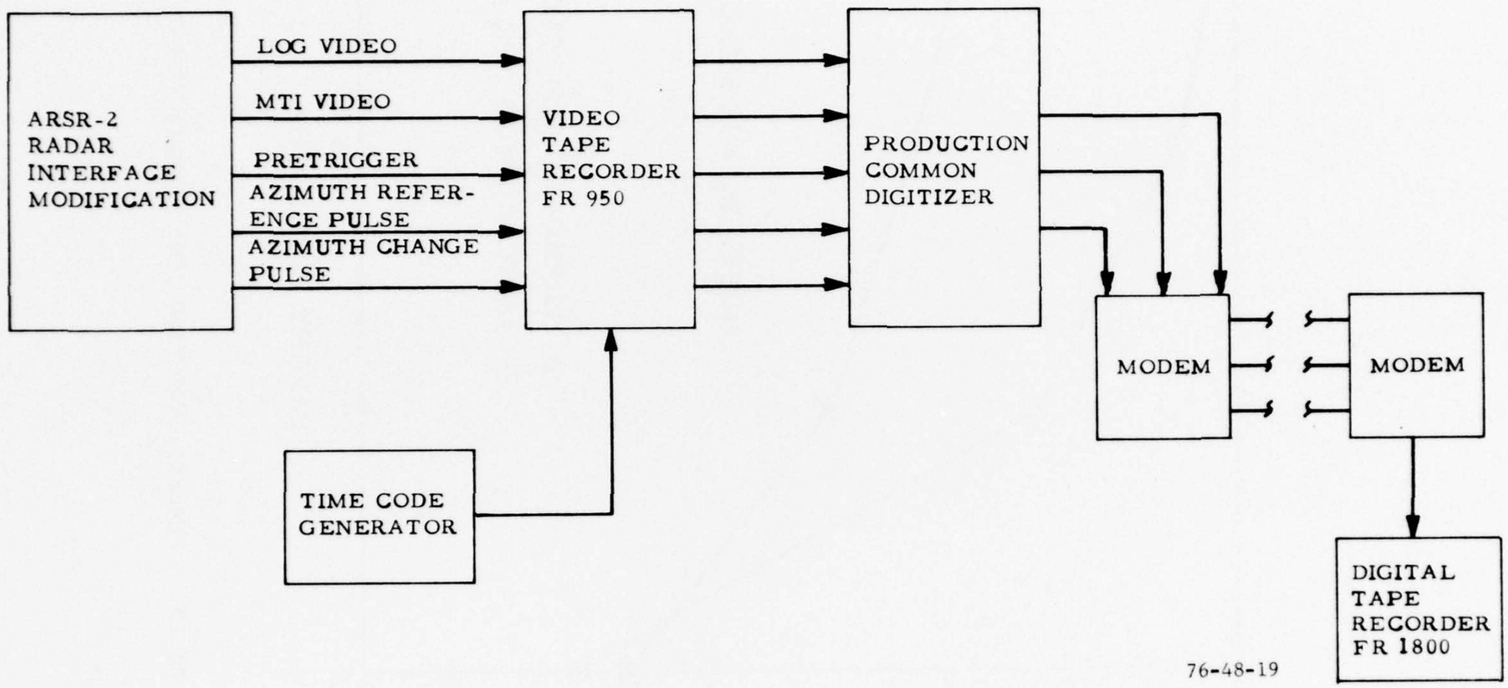


FIGURE 13. DYNAMIC TEST CONFIGURATION

APPENDIX A

PERFORMANCE CRITERIA DEFINED

1. P_D - the amount of data contained within the time interval of interest. In equation form:

$$P_D = \frac{\text{number of scans the target is reported}}{\text{total number of scans in interval of interest}}$$

2. False Target Rate - a false target is a search message which is not associated with any scan-to-scan search aircraft trail.

3. ACE Total Blank Area - the number of radar range cells in which the lead edge criteria for the sliding window exceed the sliding window size.

4. Track Blip/Scan Ratio - the amount of data contained within the track life.

5. Trail Blip/Scan Ratio - the amount of data contained within the trail life (same as P_D).

APPENDIX B

CALIBRATION OF THE CONTRACTOR'S RANK-ORDER QUANTIZER

During the initial familiarization and testing of the contractor's rank-order quantizer (ROQ), a calibration procedure had to be developed. The procedure employed is given below.

Step 1. Place 2 volts mean peak LOG receiver noise at the input to the ROQ delay line. This same voltage will appear at the input of the first comparator of the video sampling array. Take a voltage measurement at the noise input of the comparator. Now adjust the voltage on the target input on the same comparator to match the previous measurement by adjusting the center tap gain.

Step 2. Monitor the summer's quantized voltage levels on a scope. (The voltage steps were measured and found to change by 150 millivolt jumps.) Adjust resistor R38 on card DE-DD01 to cause the jump (150 millivolts) in the rank threshold each time the threshold setting is changed by 1.

Step 3. Place 2 volts mean peak LOG receiver noise at the input to the delay line. Use an electronic counter to count hits from a hit sampler (see HIT SAMPLING CIRCUIT). Adjust the threshold offset (R40 on card DE-DD01) until a count of 4-percent hits is obtained. Now set 250 millivolts mean peak LOG receiver noise at the input to the delay line. Adjust the center tap bias (R29 on card DE-DD45) to produce a hit count equal to 4 percent of total hits.

Step 4. Step 3 is repeated until a hit count of 4 percent is obtained at settings of 2 volts and 250 millivolts LOG receiver noise without any further adjustments.

APPENDIX C

VIDEO TAPES AND CD SETTINGS

FR-950 Tapes Selected for Evaluation of Rank-Order Quantizers.

Tape 1 -	Elwood No. 74-13 (3/21/74)	LOG/MTI video severe weather clutter
Tape 2 -	Elwood No. 74-20 (9/13/74)	LOG/MTI video clear air
Tape 3 -	Elwood No. 76-07 (6/22/76)	LOG/MTI video weather clutter
Tape 4 -	Paso Robles No. 2 (4/14/74)	LOG/MTI video ground clutter
Tape 5 -	Elwood No. 75-09 (6/19/75)	LOG/BCN video weather clutter

The Elmwood CD switch settings are as follows:

	Crossover	
Sliding Window = 12	074	070
T_L = 7	025	054
T_L-T_T = 2	054	060

Minimum Run Length Range 1 = 48

Zone 1-min run length = 8
Zone 2-min run length = 8

Maximum Run Length Range = 40

CD switch settings used with Paso Robles are:

Sliding Window = 12	074	470
T_L = 7	006	333
T_L-T_T = 2	054	277

Minimum Run Length Range = 48

Zone 1-width = 8
Zone 2-width = 8

Maximum Run Length Range = 40

HWD = 4.6 seconds